PRELIMINARY STUDIES IN POPULATION ESTIMATION OF TWO SPECIES OF STICK INSECTS (PHASMATIDAE PHASMATODEA) OCCURRING IN PLAGUE NUMBERS IN HIGHLAND FOREST AREAS OF SOUTH-EASTERN AUSTRALIA.

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(Four Text-figures.)

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Synopsis.

Plagues of the phasmatids *Didymuria violescens* (Leach) and *Podacanthus wilkinsoni* Macleay have occurred in certain highland areas of south-eastern Australia; these are shown on a map and the current series of outbreaks is briefly discussed. The behaviour of these insects in so far as it affects their feeding, oviposition, dispersal, life history and their host preferences is discussed.

The method of predicting the occurrence of plague numbers of nymphs and adults, based on field sampling of the egg stage, is outlined and the results obtained critically examined.

Sampling methods and the procedure adopted are stated, the shortcomings of these and suggestions for their improvement being also stated.

Methods of estimating numbers of nymphs and adults by the frass fall method are described and the application of this method in assessing the effects of aerial application of insecticide mentioned. Estimation of numbers of females by measurement of egg production is described and discussed and the results of these methods examined. The application of these methods to provide accurate figures of numbers of phasmatids for studies in population ecology is reviewed and suggestions are made for improvements and refinements of the various techniques employed.

Introduction.

Populations of the stick insects *Podacanthus wilkinsoni* Macleay and *Didymuria violescens* (Leach) (Phasmatodea Phasmatidae) have been recorded as reaching plague proportions at intervals since 1880 in the highland forests of south-eastern Australia (Macleay, 1881; Olliff, 1891). Outbreaks have occurred intermittently since then and Froggatt (1905) records an outbreak in the Nowendoc distinct in 1905. These outbreaks were probably as severe as those of the current series, but, since the forested areas are now smaller, extensive defoliation must now be regarded far more seriously.

Since 1947, outbreaks have been recorded in the Nundle area (Nundle, Hanging Rock, Tomalla, Nowendoc and Tuggolo State Forests), the Jenolan area (Jenolan and Konangaroo State Forests) and the southern highlands of New South Wales and Victoria, Bago State Forest, the Snowy Mountains Area in N.S.W., and the highlands of the Mt. Bogong, Mt. Stanley and Mt. Pinnibar areas and near the Eildon Weir in Victoria (see map).

The outbreak in the Nundle area reached a peak in the 1949–50 summer season, and in 1951–52 very serious and extensive defoliation occurred followed by a sudden reduction in phasmatid numbers over extensive areas. The decrease in numbers was only temporary and the population again reached plague numbers a few years later, notably in the Tuggolo State Forest which was devastated in the 1955–56 season and most of the remaining forested area (except for areas burnt late in 1957) in the 1957–58 season. In the Jenolan area there was no such spectacular crash and defoliation resulted in the deaths of large numbers of trees over many thousands of acres. A widespread fire in the summer of 1957 in this area also destroyed large numbers of phasmatids.

In the Nundle and Jenolan areas two species of phasmatid, *D. violescens* and *P. wilkinsoni*, occur in plague numbers, though the latter is probably responsible for the greater part of the defoliation. In the southern highlands area, *D. violescens* alone is involved. Adults of *P. wilkinsoni* are most abundant during the even numbered years and those of *D. violescens* during the odd numbered years.

In the Bago area serious defoliation was first noticed during the 1952–53 season and has recurred every second year up to the present time. More intensive investigation has revealed the occurrence of other concurrent outbreaks further south.

In all areas most of the outbreaks have occurred at elevations of more than 2,000 feet above sea level, but it has been noted that the most intensive defoliation has occurred at altitudes above 3,000 feet. It has also been noted that the southern limit of the distribution of *P. wilkinsoni* coincides with the northern limit of the winter rainfall zone.

The following table illustrates the general climatic conditions occurring in the areas where outbreaks have been recorded:

Area.	Mean Temperature of Coldest Month. (M T C M)	Mean Temperature of Hottest Month. (M T H M)	Mean Annual Rainfall. (M A R)	Occurrence of Lowest Rainfall.
Mt. Warning	55°–67°	Over 75°	60″–100″	Winter or spring.
Nundle	46°–55°	Over 75°	Below 40″	,, ,,
	34°–46°	Over 72°	Over 60″	,, ,,
Jenolan	34°–46°	Below 72°	40″–60″	,, ,,
Bago S.F.	34°–46°	Below 68°	40″–60″	Summer and autumn.
Snowy Mountains	34°–46°	Below 68°	Below 40″–over 60″	,, ,,

(*After* de Beuzeville: A Climatological Basis for Forestry.*)

BIOLOGY AND BEHAVIOUR.

Until recently it was not known that two species of phasmatid were present in certain affected areas, and Froggatt (1923) records *D. violescens* as an immature stage of *P. wilkinsoni*. In the Nundle and Bago areas it has been observed that there were some nymphal and adult phasmatids present each year with high numbers in each alternate year. Richards (1953) recorded this for *P. wilkinsoni* and the same is true of *D. violescens*. A two-yearly life cycle predominates in both these species (except in the case of a population of *D. violescens* occurring in the Mt. Warning area) and the term "semi-voltine"† is proposed to describe this.

By far the longest part of the life cycle of these phasmatids is spent in the egg stage. Eggs laid by the adult females during the late summer and autumn of one season generally lie in the forest litter for up to eighteen months and hatch during the spring of the second year after oviposition.

The eggs may be parasitized, soon after being laid, by several species of small wasps, *Myrmecomimesis* spp., of the family Cleptidae (Riek, 1955; Riek, personal communication, 1956), but these do not exercise a great degree of control on this stage. The wasp larvae develop at the expense of the phasmatid embryo and, instead of the eclosion of a phasmatid nymph, a mature wasp emerges from the egg.

After eclosion the phasmatid nymphs climb any vertical object. Occasionally this is the stem of a *Eucalyptus* sp., and after reaching the terminal branchlets the insect commences to feed on the leaves.

Most species of *Eucalyptus* are acceptable as food, though the narrow-leaved peppermints, *E. radiata* Sieb. and *E. robertsoni* Blakely, the broad-leaved peppermint *E. dives*

* A summary of evidence given before the Commonwealth Reconstruction Committee, September, 1943.

† i.e., having half a generation per year.

Schauer and the gums *E. viminalis* Labill., *E. huberiana* Naudin, *E. dalrympleana* Maiden, *E. mannifera* (A. Cunn. Herb.) Mudie, *E. stellulata* Sieb., *E. pauciflora* Sieb. and *E. bicostata* Maiden, Blakely and Simmonds appear to be favoured species and are the first to be defoliated. Other species which are known to have been severely defoliated are *E. laevopinea* R. T. Baker, *E. obliqua* L'Hérit., *E. delegatensis* R. T. Baker and *E. fastigata* Deane and Maiden, though these appear to be less favoured than the former groups.

In the field no other genera have been found to be eaten, though *Angophora* sp. has been accepted as food in captivity.

The reason for this preference is not known, but it appears in all areas of defoliation that in both sequence and intensity the order 1. peppermint, 2. gum-barked and 3. rough-barked is observed.

Quite often the nymph may climb a grass stem or some other plant unacceptable as food. Should this occur it drops off or climbs down to the ground and continues its searching. Most of this activity takes place in daylight and is usually confined to periods when the relative humidity is high.

This process of searching at first appears to be at random and solely a result of the negative geotaxis exhibited by these insects, but there also appears to be a visual appreciation of the situation by the insect and an individual phasmatid may seek out the nearest tallest object. If this is a suitable source of food further searching is inhibited, but, if not, the searching proceeds until food is found or death occurs.

The behaviour of the nymph is influenced by the composition of the forest association into which it has ecloded. If the understorey consists of *Eucalyptus* sp. trees or saplings, numbers of nymphs will be found on the foliage of these as well as that of the understorey trees. As the insects grow and as the food supply is depleted the nymphs will move to these from the smaller trees. The phasmatids themselves will tend to modify the composition of the stand since repeated defoliation will kill seedlings and even large trees of certain poorly refoliating species such as some of the "Ash" group (*E. delegatensis* and *E. fastigata*). If numbers are high and defoliation is intense for several seasons in succession even the more resistant tree species will be killed. In any case, the extreme negative geotaxis exhibited by these phasmatids results in the newest shoots of the current year's growth being the first to be defoliated. This results in energy, normally devoted to the general growth of the tree, being diverted to refoliation, resulting in loss of wood increment during the current and often the succeeding year during which most refoliation takes place. Many *Eucalyptus* sp. in the highland regions, although not deciduous, have a marked dormant period during the winter and a flush of growth during the warmer period of the year.

Quite often when phasmatids are feeding or resting on small trees they react to any movement, the near approach of an observer being sufficient to cause them to drop from the foliage, when they may move toward any upright object which may even be the observer. Both nymphal and adult phasmatids are markedly negatively geotactic and are usually found feeding on the leaves of the terminal shoots, retreating from these only when the food supply is exhausted or if there is excessive crowding.

It has been observed in the field, but particularly in the case of caged phasmatids nearing maturity, that much of the food provided for them is wasted because of the insects' habit of biting through the leaf near the petiole, resulting in the excision of a large part of the leaf-blade. An insect may fall with the excised portion of the leaf, which it then abandons and climbs to another branchlet where it resumes feeding. This occurs in the field also and results in a more rapid defoliation than would be the case if the insect consumed all of the leaf. Both this and crowding contribute to the cyclic movement of the phasmatids which, when numbers are high, are continually falling or gliding to the ground only to reclimb the nearest vertical object.

Dispersal.

References sometimes made to the dispersal of these phasmatids suggest that the population appears to increase in localized areas and then disperses or migrates as do the plague locusts. It is the opinion of the writer that this is not so and that these outbreaks are the result of static populations increasing in density in discrete areas throughout a wide range in which the phasmatids commonly occur.

When population density is low, procryptic coloration of the phasmatids renders detection of the insects difficult. Severe defoliation, as well as the presence of insects dislodged from the trees because of crowding, usually occurs before they are noticed by inexperienced observers. Population increases often appear very localized because of limited observation, but, as investigations are intensified, larger areas may be found to be affected, giving the impression of a focus of infestation spreading out. Some dispersal of phasmatids within affected areas does occur through transport of young nymphs on air currents or by the limited flight of adult insects.

As well as the predisposing factor of host preference, the food supply actually available often influences the distribution of the population within areas of high density. If food is not a limiting factor at maturity, the female phasmatids may drop their eggs anywhere beneath the crown of a tree on the forest floor. If it becomes exhausted in certain localities, they either die or move to the margin of the defoliated areas or to certain trees which, by chance or for other reasons, have not yet been defoliated. This may result in a patchy distribution of the eggs over the forest floor, with the highest numbers often being found at the edges of the seriously defoliated areas.

Males of *P. wilkinsoni* and *D. violescens* often travel sporadically in flight for considerable total distances during their lifetime, but they must launch themselves from elevated positions and cannot rise from the ground as do the males of *P. viridoroseus* (Gray). Females do not fly at all, but merely glide for short distances; in this respect *D. violescens* is more limited than *P. wilkinsoni* because of the former's relatively smaller wings. Consequently, differential dispersal of males and females is not uncommon and high numbers of males with low numbers of females, or vice versa, are observed in certain localities through an area of outbreak. As a result females may be unfertilized or competition by males for copulation with the females may be intense. Unless parthenogenesis is common, and this has not yet been demonstrated for either of these species, this may account for part of the proportion of eggs which fail to develop for unknown reasons and for their pattern of distribution over the forest floor.

Methods of Population Estimation.

Egg Stage.

Since both these species of plague phasmatids are semi-voltine the possibility of assessing population trends by sampling the egg stage was soon recognized. At first, egg collections were made at random in the forest litter several times a year in areas which had been defoliated and examinations of eggs were made to ascertain the stage of development of the embryo and the effects of any parasitism or disease. A high percentage of embryonic development alone was used, at this time, to predict a probable outbreak, without any attempt being made to relate this to actual numbers of insects expected to be present.

Although the predictions made on this basis were in fact correct, the method was most imprecise. Some interesting biological data were obtained from this work, however.

Figures 1 and 2 illustrate the results obtained by this procedure at Bago State Forest No. 560 near Batlow, N.S.W. Eggs were collected from 25 sites at intervals of about three months throughout the period and approximately 15,000 eggs were dissected.

Each egg was inspected by removing its operculum and examining the contents by means of a low-power binocular microscope. If reasonable care was exercised the vitelline membrane was undamaged and in many cases the phasmatid embryo or wasp parasite larvae continued to full development. Eggs were classified under the following headings: (1) Fully developed embryo. (2) Partly developed embryo. (3) No embryonic development visible. (4) Parasitized. (5) Contents diseased or deteriorating. (6) Empty shell.

The results were expressed (*a*) empty shells as a percentage of the total sample, and (*b*) eggs with contents as a percentage of the total less the number of empty shells.

The lines depicting development of the embryo indicate the rapid development during the early summer of the year following oviposition. After this time very little further development of the embryo could be detected except that the amnionic cavity became less moist as the time of eclosion approached.

It may be inferred from the increase in the number of empty shells in the early summer period of 1955 that a definite eclosion of one segment of the phasmatid population took place, although the greater proportion of the eggs did not hatch. The two probable explanations for this are that either one population segment is univoltine and the other semi-voltine or that both are semi-voltine, one segment being low density and the other high.* It has been observed in the field in the case of both *D. violescens* and *P. wilkinsoni* that there are a few nymphal and adult phasmatids present each year with high numbers in alternate years.

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* More recent work has revealed that at Bago the latter explanation is correct and that both segments of the *D. violescens* population are semi-voltine.

Eggs parasitized by the Cleptid wasps were not readily detectable until the wasp larvae were obvious within. In the parts of the forest where Alpine Ash, *E. delegatensis*, predominated, the percentage of parasitism was low, but where Mountain Gum, *E. dalrympleana*, predominated it was considerably higher, though not sufficient to exercise any appreciable measure of control, and did not affect the egg population to a

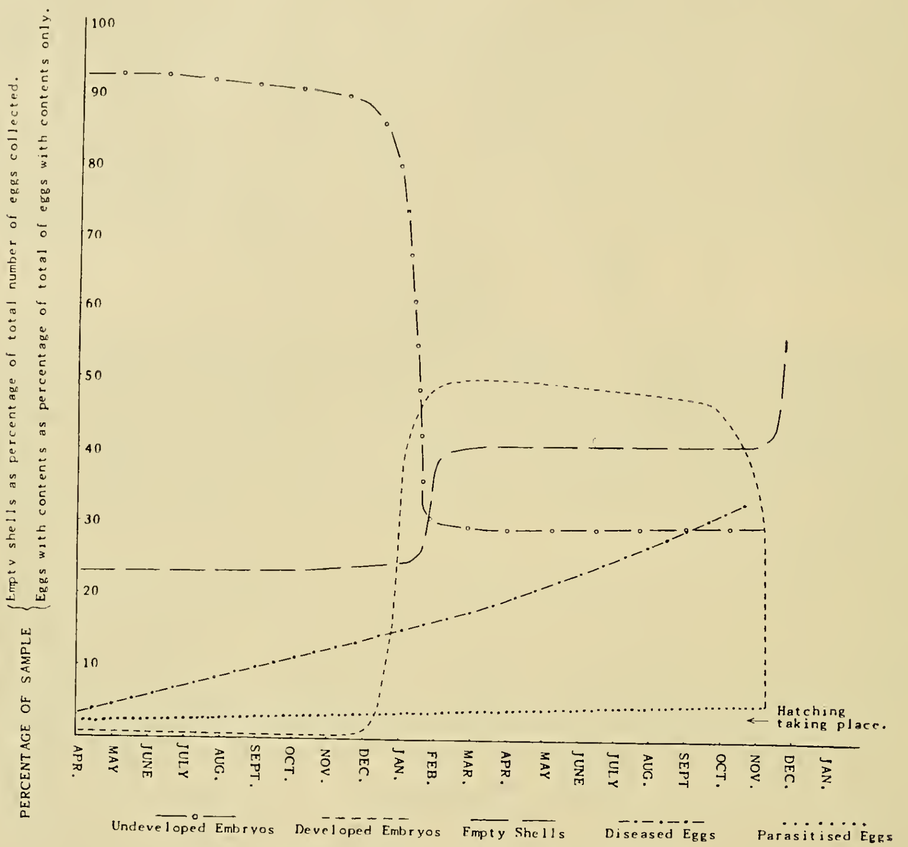

Fig. 1.—Alpine Ash, *E. delegatensis*, predominates.

very marked degree. There was a definite fall in the percentage of parasitism after the summer period suggesting that segment of the parasite population was in phase with one segment of the phasmatid population and that some adult wasps emerged in time to oviposit in the eggs laid that season by the phasmatids. Most of the parasites, however, did not emerge until the following summer. Most mortality in the egg stage was attributed to "disease and deterioration", although the factors involved were not identified.

It was soon realized that this method provided only information of the state of the egg population without indicating the probable insect numbers which could be expected at eclosion.

The primary concern of the writer was to predict the probable occurrence of plague numbers of phasmatids throughout the areas affected. The areas concerned were widely separated and occasionally the services of employees of the various interested authorities were of necessity required for sampling. The separation of the eggs from the litter was slow and laborious, even with the aid of a mechanical sieve shaker, the final search for eggs of necessity being done by hand.

SAMPLING.

The sites for sampling were chosen observing the following provisos: (1) The eggs are dropped by the female phasmatids onto the ground from the foliage of trees so that sites should not be located in the open. (2) It is probable that eggs would be found mainly near the margin of areas which had previously been totally defoliated and most sites should be located to sample this. (3) In an area where defoliation was

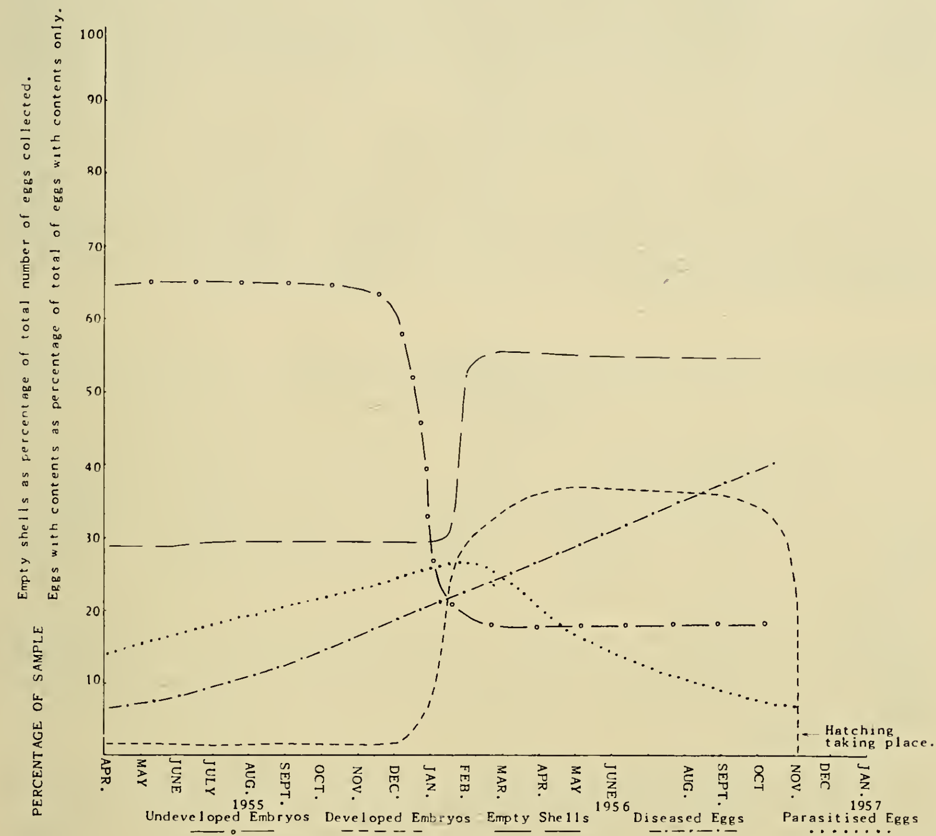

Fig. 2.—Mountain Gum, *E. dalrympleana*, predominates.

not complete, it is probable that the eggs will be found anywhere throughout the area and the sites could be located at random. (4) Sites should not be located in areas where there will be interference subsequent to the natural distribution of the eggs, e.g., roads, tracks, gutters or localities subject to the wash of water. (5) In areas where defoliation is widespread and variable an attempt should be made to sample localities of varying defoliation intensity. (6) Sites should be reasonably accessible at all times of the year. Within these limits plots were located without bias.

The actual sampling of the eggs in the field was standardized as follows: a plot of one square yard was measured, all grass, etc., chipped off with a hoe and all the litter down to the mineral earth collected together. This litter was sieved, mesh apertures being chosen so that a certain fraction would contain the eggs. This fraction was taken to the laboratory to be further sieved if necessary and all eggs, including the empty egg shells, were removed by hand.

Egg estimation studies were initiated by the writer in the Kiewa Area, the Island Bend Area, the Bago State Forest and the Nundle group of State Forests. Most of the litter collections in the field were made by the staff of the Electricity Commission of

Victoria and the Snowy Mountains Hydro-Electric Authority in areas where they were concerned, all sorting and examination of the eggs being made in the laboratory of the Entomological Research Section of the Forestry Commission of N.S.W.

Nundle Area.

During the 1955–56 season almost complete defoliation of a large area of Tuggolo State Forest was caused by nymphal and adult phasmatids (mainly *P. wilkinsoni*), and it appeared probable that an increase in numbers could be expected in the adjoining forests during the 1957–58 period. An egg survey was carried out to determine the probable population density and to provide a choice of locations for an experimental insecticidal treatment which was to be applied by aircraft when the phasmatids were in the nymphal stage.

The results of dissection of eggs obtained by litter sampling during the survey are contained in Appendix 3. Since the total area of forest involved was large (about 43,000 acres) and the greater part not readily accessible except by foot, the plot sites attempted to sample known differences of past defoliation in Tuggolo State Forest and in accessible areas on Tomalla and Nundle State Forests, the sites being placed at random in the latter two forests.

TABLE 1.

Numbers of Eggs per Acre (Excluding Empty Shells), Minimum and Maximum, Potential Phasmatid Population at Eclosion per Acre—Minimum, Maximum and Mean.

State Forest.	No. of Samples.	No. of Eggs/Acre.		P.P.P. at Eclosion/Acre.		
		Minimum.	Maximum.	Minimum.	Maximum.	Mean.
Tuggolo ..	9	42,000	1,230,000	3,000	357,000	72,000
Tomalla	4	63,000	189,000	6,000	69,000	33,000
Nundle	7	21,000	483,000	3,000	159,000	43,000

The litter samples collected in June, 1957, were each taken from a quadrat one square yard in area, and it is possible to relate the numbers per square yard to numbers per acre of forest floor if the average crown cover of the area is taken into account. Numbers of eggs and of expected phasmatids are expressed in this way in all the following tables.

The formula $\frac{\text{No. of square feet per acre}}{\text{No. of square feet per quadrat}} \times$ average crown cover per cent. was used; the average crown cover was estimated visually at about 60 per cent. so that a factor of 3,000 was obtained:

$$\left(\frac{43{,}560}{9} \times \frac{60}{100} \doteqdot 3{,}000 \right)$$

The figures obtained by examination of the eggs collected from the litter samples are shown in Appendix No. 1 and numbers of the following order estimated to be present. The number of phasmatids expected at eclosion or "potential phasmatid population at eclosion" was calculated by using the figures for "eggs with developed embryos". These could, by this time, be reasonably expected to hatch in the coming spring.

Since very little information was available it was arbitrarily determined by the writer that if a population of about 50,000 late instar nymphal or adult phasmatids per acre could be expected then defoliation in the area would be serious and probably complete.*

A critical examination was made of the figures obtained, and it was predicted on the available evidence that plague numbers of phasmatids would be present throughout

* This figure was derived from a population estimation study carried out at Bago State Forest in the previous year.

the area with intensive defoliation over much of it, particularly Tuggolo and Nundle State Forests.

Eclosion of phasmatid nymphs took place as expected and incipient defoliation was evident throughout the area. Severe fires during November, 1957, burnt over a large portion of Tuggolo State Forest, part of Tomalla and a small part of Nundle State Forest. These markedly reduced the phasmatid population on the burnt areas which included that set aside for the experimental spraying. Studies of the nymphal and adult numbers planned to assess this were as a result not carried out. However, the area was inspected during March, 1958, by Forester N. C. Gare, Tamworth Subdistrict. and the writer and the following observations recorded:

State Forest.	*Extent of Defoliation.*
Nundle	Very severe, mostly complete defoliation.
Tomalla	Defoliation light to medium on unburnt area—about 1,500 acres affected.
Tuggolo	Defoliation light to medium throughout the whole forest, greater in the south where defoliation was advanced before fire reduced phasmatid numbers.

TABLE 2.

Total Number of Eggs per Acre (Excluding Empty Shells), Expected Maximum, Minimum and Mean Numbers of Phasmatids at Eclosion per Acre.

Date of Collection.	No. of Eggs/Acre.		Potential Phasmatid Population at Eclosion/Acre.		
	Minimum.	Maximum.	Minimum.	Maximum.	Mean.
31/10/57	3,000	174,000	0	9,000	1,500 (1957/58)
			3,000	102,000	33,000 (1958/59)
3/ 3/58	0	171,000	0	72,000	16,000 (1958/59)
			0	18,000	4,000 (1959/60)

It was obvious that the only part of the area which had escaped serious defoliation on Tuggolo and Tomalla was that burnt in November, 1957. It was concluded that the sampling carried out was quite adequate for a general prediction of high numbers followed by extensive defoliation. However, it was quite apparent that the population density, at least at eclosion, was very variable throughout the area and that more intensive ecological studies would require a much greater intensity of sampling.

Kiewa Area.

Egg estimation studies were initiated by the writer at the request of the State Electricity Commission of Victoria following noticeable population increases of the phasmatids in the Bogong–Mt. Beauty area. Twelve sites were chosen, observing the prescribed conditions, and litter samples one square yard in area were collected from each site. Eggs collected from these samples were examined and the results are shown in Appendix No. 2.

Using the figures obtained, numbers of the order shown in Table 2 were estimated to be present in the area.

(These figures were derived from the dissections, again using the factor of 3,000 obtained as indicated.)

The Potential Phasmatid Population at eclosion for each year was calculated by using the number of eggs with developed embryos found in the samples collected in

October, 1957, in the case of the year 1957 and the number of eggs with undeveloped embryos in the case of the year 1958. By the time of the next sampling in March, 1958, these embryos had developed and the expected numbers at eclosion were again calculated in a similar manner.

The fall in the expected numbers (P.P.P. at eclosion) per acre is most probably due to disease or deterioration with a slight increase in discernible parasitism. (See Appendix 4 for details.)

It was predicted that there would be low numbers of *D. violescens* present during the 1957–58 season and slight defoliation would occur, but that medium to high numbers could be expected during the 1958–59 season with serious defoliation in certain localized areas, i.e., above Bogong township, in the vicinity of the 6–7 mile peg on the No. 1 Road and near the Pretty Valley Bridge.

The area was inspected during February, 1959, and this prediction was found to be reasonably accurate. The sampling carried out was adequate, but could be extended to other areas of infestation in the vicinity which were known.

Snowy Mountains Area.

D. violescens was present in large numbers and serious defoliation occurred around Island Bend in the 1955–56 season. Five sites were sampled in this area by staff of the Snowy Mountains Hydro-Electric Authority following directions given by the writer. The results obtained by examination of the eggs collected from these samples are given in Appendix 3.

Estimated numbers using the results obtained are shown in Table 3.

TABLE 3.

Maximum and Minimum Number of Eggs (Excluding Empty Shells) per Acre; Maximum, Minimum and Mean Number of Phasmatids per Acre Expected at Eclosion.

Date.	No. of Eggs/Acre.		Potential Phasmatid Population at Eclosion per Acre.		
	Minimum.	Maximum.	Minimum.	Maximum.	Mean.
June, 1957	6,000	477,000	3,000	51,000 (1957/58)	23,000
			63,000	202,000 (1958/59)	101,000

Using these figures as a basis it was predicted that moderate numbers of *D. violescens* would be present in this area, with high numbers in localized areas during the 1957–58 season. High numbers could also be expected during the 1958–59 season.

The area was inspected during April, 1958, and, as expected, phasmatids were present and serious localized defoliation had occurred. It was known to the writer, however, that high numbers might occur over a much more extensive area than the locality from which the samples were drawn and it was recommended to the Authority that litter samples be collected from such areas (particularly the Geehi area). Owing to shortage of staff this was not done and the prediction for the 1958–59 season had to be based on the samples drawn in June, 1957. No confidence was placed in this prediction by the writer because of lack of information as to subsequent embryonic development of the eggs.

Intensive defoliation did occur during the 1958–59 season in the Geehi area with a less severe infestation at Island Bend (unpublished report, Dr. M. E. Phillips, Soil Conservation Report No. SS1040, S.M.H.E.A., March, 1959), and an inspection by the writer during April, 1959, confirmed this report.

The sampling carried out in this area was quite inadequate to obtain the information required for an accurate estimate of expected numbers to be made. Sampling sites should have been located for this purpose within the areas of expected or suspected population increase.

Bago State Forest.

Nymphs and adults of *D. violescens* were expected to be present in high numbers in the Bago area during the 1958–59 season and an experimental aerial spraying was planned during this period. An area of about 500 acres comprising Compartments 34, 35 and part of 36 and carrying high site quality Alpine Ash, *E. delegatensis*, was chosen.

So that accurate estimate of numbers of the various stages could be made, seven sites were chosen at random within the area and litter samples one square yard in area were drawn from each site in March and again in September, 1958.

Figures obtained by examination of the eggs collected from the litter samples are detailed in Appendix 4. The estimations made using the figures obtained by examination of the eggs are shown in Table 4.

The expected number of phasmatids at eclosion for the current and succeeding season were calculated as explained above.

The apparent decrease in the potential phasmatid population at eclosion is partly attributable to the death of advanced embryos and to disease and deterioration. If the figures are examined as percentages (see Appendix 4), it appears that the sampling, which was not carried out quite as prescribed because of bad weather and difficulty of access to the area, was responsible for a fair proportion of this. Only five samples were taken instead of seven, and at least one of the high density sites was missed.

TABLE 4.

Maximum and Minimum Number of Eggs per Acre, Excluding Empty Shells; Maximum, Minimum and Mean Expected Numbers of Phasmatids at Eclosion per Acre (Total Number of Eggs Including Empty Shells in Brackets).

Date.	No. of Eggs/Acre.		Potential Phasmatid Population per Acre at Eclosion.		
	Minimum.	Maximum.	Minimum.	Maximum.	Mean.
19/3/58	1 80,000	1,107,000	24,000	513,000	185,000 (1958/59)
	(201,000)	(1,467,000)	12,000	123,000	51,000 (1959/60)
30/9/58	120,000	537,000	18,000	168,000	77,000 (1958/59)
	(156,000)	(1,107,000)	6,000	69,000	28,000 (1959/60)

The intensity of sampling in this locality was much greater than that undertaken in other areas, since it was hoped to make estimations of the numbers of insects in the nymphal and adult stages of the insect both as a study of natural mortality and of the effects of the intended insecticidal treatment.

It was considered that the expected numbers at eclosion were great enough for a prediction of high numbers during the 1958–59 season with the probability of serious defoliation in the area chosen for treatment.

The planned census work on the nymphal and adult stages was not carried out due to circumstances beyond the writer's control, but the area was inspected during April, 1959. At this time, adult phasmatids were numerous and defoliation of this portion of the forest was intensive.

Nymphal and Adult Stage.

The nymphal and adult stages of both *D. violescens* and *P. wilkinsoni* are less easily sampled than the egg stage, because of the insects' behaviour and habitat.

Populations of the young nymphs have been sampled directly from small trees in limited localities by the writer, taking branchlets of a given length and using a catching frame to retain insects which dropped from the sample. This was satisfactory where most of the trees were small and could be easily reached by hand, but it restricted the study to a small stratum of the habitat and could not be used for large trees. As mentioned before, the insects are quite often sensitive to the mere approach of an observer, and may drop from the foliage if a shadow merely passes over them. Apart from the physical difficulty of reaching the top-most foliage, this behaviour must be taken into account when choosing a method for estimating numbers of the insects.

The frass pellet of a phasmatid is roughly cylindrical in shape and up to approximately 0·2 × 1 cm. in the case of a mature female *P. wilkinsoni.* The pellets of males are always smaller and lighter than those of a female of corresponding age. The ratio of the average weight of a mature male : mature female pellet of *D. violescens* is very close to 1:3. The pellet is compact, relatively dry, and holds its shape for up to several months. The frass of small nymphs may be dispersed by the wind or may be retained by moist foliage, but this is not the case with that of adult insects.

An experimental aerial spraying to control *D. violescens* at Bago S.F. was planned in 1957 and the writer had to determine the relative effectiveness of the insecticides used. Time, assistance and finance were all limited and, after due consideration, the method of frass-fall measurement was adopted. It was hoped that by comparison of the amount of frass fall before and after treatment an accurate appraisal of the effectiveness of the treatment could be made.

Frass Fall Measurement Method.

An area of 900 acres comprising portions of Compartments 13, 14, 15, 19, 20, 37, 39 and 40 mainly of high site quality Alpine Ash, *E. delegatensis*, was chosen and divided into three sections. Sixty frass traps located approximately on a 10-chain grid were located within the area, 20 to each section; traps were placed so as to be beneath the crown of whichever tree happened to be near the surveyed point, no choice being made with regard to size or species (provided it was a *Eucalyptus* sp.). (Unpublished Reports, F. J. Gay, Division of Entomology, C.S.I.R.O., Canberra, and K. G. Campbell, Forestry Commission of N.S.W., 1957.)

Frass Traps.

The frames of the frass traps were 5 feet by 5 feet in dimension and constructed of 1″ × 1″ hardwood joined by nailing at the corners with triangular plywood gussets. Four legs also of 1″ × 1″ hardwood were provided with plywood retaining pieces nailed to the top forming a slot into which the frame fitted, and sharpened so that they could be driven into the ground. The frame could be placed horizontally on practically any surface, and once the legs were driven into the ground the frame could be removed and replaced without moving them.

Over the frame was stretched doubled "mosquito" netting, the edges of the netting being slipped over small brads which had been nailed into the frame. Any damaged netting could thus be quickly removed and renewed. A tape was fixed to the centre of the netting which was tied to a stake about a foot long driven into the ground. This prevented the netting from flapping in the wind. The stake was provided with a loop so that the tape could be easily untied to remove the frame for clearing.

The traps were constructed entirely in the field using a hammer, saw and axe (the gussets being prefabricated), the procedure for location being as follows: The frames, legs, netting and stakes were conveyed as close as possible to the sites by motor vehicle (usually within twenty chains) and thence carried to the required place. First the frame was placed as desired and the legs placed and driven in until the frame was horizontal. The frame was then removed and the central stake driven in. The netting was then stretched over the frame which was replaced on the slotted legs and the tape tied to the stake. The traps were numbered B1–B20, C1–C20 and D1–D20 respectively.

Frass Collection.

As soon as the 60 traps were in position, frass collection commenced. Recordings were made, the time of location of each trap and at each succeeding time a trap was cleared of frass. Clearing was accomplished as follows: The tape was untied from the stake, the frame removed and the contents tipped onto a plastic sheet. The frame was replaced and the sheet picked up by the corners so that all the contents moved to the centre. These were carefully scooped into screw-top metal canisters (export cigarette tins) and a tag giving the number of the trap included within. Traps were cleared daily and about 36 man-hours per day were required for this purpose.

After all traps had been cleared, each batch was tipped onto a tray and all extraneous matter, pieces of bark, leaves, buds, flowers and excreta of other insects was removed by hand. Each batch was then placed into a separate drying tin and dried to constant weight. This took about 18 man-hours per day. The total quantity of frass fall per 20 traps per collection hours is shown in Appendix 5. This was reduced to frass fall per hour for each trap by computing:

$$\frac{\text{Weight of frass fall per collection per trap}}{\text{Period of time since last collection}}$$

The mean frass fall per hour is given in Table 5.

TABLE 5.

Bago State Forest.

Frass Fall in Grammes per 25 Square per Hour (Mean ±95% fiducial limits).

Period.	Control Area C.	Dieldrin Sprayed Area D.		B.H.C. Sprayed Area B.
5– 8/3/57	0·180±0·020	0·149±0·026	5– 7/3/57	0·051±0·008
9–12/3/57	0·158±0·020	0·152±0·034	8–12/3/57	0·053±0·004
5–12/3/57 inclusive	0·170±0·015	0·150±0·022	5–12/3/57 inclusive	0·052±0·006
3– 4/4/57	0·140±0·018	0·141±0·036	3– 4/4/57	0·064±0·015

It was noted in the field that rain caused a definite reduction in the rate of frass fall, but that this increased in the following dry period and made up for the reduction. This may have been due in part to retention of the pellets by wet foliage, but a similar observation was made with caged insects which were not exposed to the rain nor on wet foliage.

The method proved very satisfactory as a means of comparison of effects of the insecticides and the writer decided to attempt to derive actual numbers of insects from the results obtained from measurement of frass fall.

Nothing was known of the rate of frass fall per insect, and as *D. violescens* was being held at Epping, N.S.W., to provide data for rate of egg production, possible parasitism, etc., it was decided to measure the rate of frass fall of these insects. The insects were held in cages (*a*) and (*b*), 9″ × 9″ × 15″, and (*c*), 18″ × 18″ × 24″. Those referred to (*a*) were reared at Epping from eggs collected in the field and (*b*) and (*c*) were taken at Bago State Forest as last instar nymphs or recently mature insects. The insects were supplied with abundant food in the form of leaves of a Peppermint, *Eucalyptus andreana*. The cages were held in a bush house which simulated, to some extent, conditions of temperature and humidity which would be experienced in the field at Bago.

The frass was collected at intervals, dried to constant weight, and the rate of frass fall per hour calculated (see Appendix 5). Male and females were not held separately as the main object was to obtain fertile eggs, but it was determined that the weight of male : female frass pellets and their rate of production were both very close to the ratio 1:3. Figures for frass production per hour male and female were derived and the results are given in Table 6.

The figures for frass production by the insects in (*c*) were used to calculate figures for the mature phasmatid population sampled at Bago, since it was considered that these would most truly reflect actual field conditions. An average crown cover of between 50 and 60 per cent. was again assumed (supported by observation) and a factor of 1,000 used for conversion:

$$\left(\frac{43{,}560}{25} \times \frac{(50 \text{ to } 60)}{100} \div 1{,}000\right)$$

This gave figures of the order shown in Table 7.

Observations made of defoliation in the field were: (1) Most serious *C*. (2) Next most serious *D*, though not much less than *C*. (3) Defoliation noticeable but not serious *B*.

TABLE 6.

Average Frass Production per Insect per Hour (Oven Dry Weight).

	Males.	Females.	
(*a*)	1	2	Male .. 0·0015 gm./hour. Female 0·0046 gm./hour.
(*b*)	2	4	Male .. 0·0019 gm./hour. Female 0·0060 gm./hour.
(*c*)	12	46	Male .. 0·0015 gm./hour. Female 0·0046 gm./hour.
(*d*)	1*	1*	Male: Max. 0·0051 gm./hour. Min. 0·0031 gm./hour. Female: Max. 0·0087 gm./hour. Min. 0·0061 gm./hour.

* Hadlington and Hoschke, 1959. Insects held in separate cages.

Measure of Egg Production.

Oviposition commenced at Bago about the first week in March, 1957, and eggs were collected from the frass traps and counted (see Appendix 6). The average number of eggs produced per day by the crowded females (Cage C; Fig. 3) at Epping was just over one per day, particularly towards the end of their egg-laying life (during April at Bago when the main egg counts were made), although this figure was exceeded when the females first commenced laying.

TABLE 7.

Average Number of Phasmatids per Acre.

Period.	Control Area C.	Dieldrin Sprayed Area D.		B.H.C. Sprayed Area B.
5– 8/3/57 ..	60,000	50,000	5– 7/3/57 ..	17,000
9–12/3/57 ..	53,000	51,000	8–12/3/57 ..	17,000
5–12/3/57 inclusive	57,000	50,000	5–12/3/57 inclusive	17,000
3– 4/4/57 ..	47,000	47,000	3– 4/4/57 ..	22,000

If a 50:50 sex ratio is postulated the number of eggs expected may be calculated from Table 7. These and figures calculated from egg production figures are given in Table 8.

The writer realizes that there are approximations in the figures presented above, but the degree of agreement obtained indicates the possibility of accurate population estimated by a combination of frass fall and egg production measurement.

DISCUSSION.

The methods of population estimation described are attempts to assess the phasmatid numbers during (*a*) the egg stage, and (*b*) the nymphal and adult stages.

The eggs are readily available for sampling as they are dropped directly onto the forest floor. For predictions of expected numbers of phasmatids or the "potential phasmatid population at eclosion" the method is considered adequate, providing the intensity of sampling is scaled to the required accuracy of the prediction or estimation.

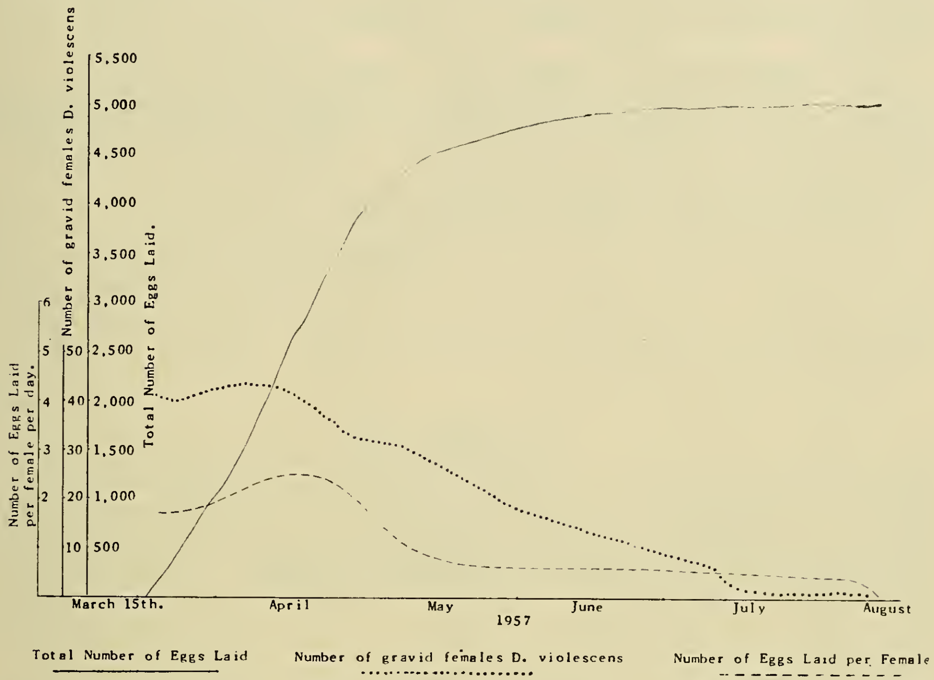

Fig. 3.—*D. violescens* held at Epping, N.S.W. Total number of eggs laid, and eggs per female per day.

Obviously, if an area prediction only is required, far fewer samples may be drawn than if a very accurate census is required, for example, a study of the population dynamics.

For the latter type of census the writer also considers that stratification of the sampling with regard to site-quality and floristic composition would be necessary.

TABLE 8.

Average Number of Eggs per Day per Trap 4/4/59.

Area.	Expected.*	Actual.†
C	24	21·7±4·8
D	24	26·8±9·8
B	6	7·5±3·3

* Mean±95% fiducial limits.

† Calculated from figure of frass production, number of females $= \dfrac{\text{Total number of phasmatids}}{2}$.

(There appears to be reasonable agreement between the figures derived by both methods.)

Although the predictions made on the basis of the figures obtained by the method outlined have proved correct, these were also based to some extent on the writer's local knowledge of the areas studied. At no time was sufficient assistance or time available either in the field or laboratory to collect or examine as many samples as the writer would have preferred.

Unless the collection sites are selected according to a pattern of past or probable courses of infestation, a quite unreal inference may be drawn from the figures obtained by examination of the eggs. Again, although the p.p.p. may be assessed with reasonable precision, it does not follow that actual defoliation of the area sampled will be as serious as might be expected from such as assessment. Little is known of the mortality factors acting on the nymphal and adult stages, nor has any attempt yet been made to measure their effects.

For a long-term study it is suggested that permanent traps of durable wire mesh ("fly wire" is adequate to retain the eggs of both *P. wilkinsoni* and *D. violescens*), placed in position prior to oviposition and laid directly on the mineral soil, should be established. Eggs falling onto these would be readily available for sampling and this would obviate the laborious separation from litter by sieving.

If numbers per acre are required, accurate measurements of crown cover per cent. should be determined for each site or at least for the area being studied.

The nymphal and adult stages are far less accessible, but the methods described seem quite satisfactory. If it is desired to carry out direct sampling of these stages some form of catching tray must be provided to intercept escaping insects which, as previously mentioned, are often very sensitive to any disturbance. This is likely to be practicable only when sampling from small trees.

The method of frass fall measurement appears satisfactory except in the case of very tall and isolated trees and first or second instar nymphs, where wind might cause the loss of portion of the frass; such a method appears suited to the estimation of numbers in intensive population studies. In the latter instars and more particularly with adult phasmatids, it is possible to distinguish between numbers of males and females if this is desired. The frass fall of *D. violescens* per day was reasonably constant (although this was affected by rain which apparently inhibited frass production). Whether the insects actually stopped feeding during the rain is not known, and this may be a result of very high humidity since caged insects not exposed to the direct effect of rain responded similarly.

The traps described were adequate in all respects, being cheap, easily constructed, light and readily handled. The double mosquito netting was quite satisfactory and retained the frass of last instar and mature insects, the netting was difficult to wet, and if wetted, dried easily. Even if the netting was damp the pellets could be removed, providing a little care was taken. Muslin may be used to cover the traps to retain the frass pellets of earlier instars. Damage was caused to these traps by wandering animals (wombats and cattle being the most troublesome).

For long-term population studies, metal frames with metal cloth covers would be more suitable, the mesh being chosen to retain the frass pellets as desired. Damage by animals may be minimized by fencing where necessary.

To convert the frass fall to numbers of insects, known numbers of phasmatids must be held in captivity under conditions as near as possible to those applying in the area being studied, the frass from these being collected and weighed as described. Some males and females should be held separately as well as together and varying sex ratios should be studied to determine the influence on frass and egg production. Adequate replications to sample the variable conditions of the area being studied are, of course, necessary.

When the insects are mature the rate of egg production appears to provide a good check against the frass fall method. The studies of egg production would be carried out concurrently with the frass studies outlined above, observing similar conditions.

These could be further related to studies of the egg stage in the field. Although these studies were initiated for the purposes mentioned, the writer was also attempting to develop suitable techniques which could be applied to a long-term study of these insects. These techniques had, of necessity, to be inexpensive and require as little labour as possible. The writer considers that the methods will prove satisfactory and intends to implement them when and wherever possible.

Conclusions.

1. The method of litter sampling and egg examination appears satisfactory for the purpose, i.e., the provision of reasonably accurate predictions of plague numbers of nymphal or adult phasmatids.

2. To obtain most accurate results, litter collections in the field should be made in late January when embryonic development is advanced, and in early September just prior to eclosion of the nymphs.

3. If long-term studies are intended, permanent plots should be established and traps with frames constructed of durable material should be provided to supplement litter samples made directly in the field.

4. The frass fall measurement method is satisfactory both for (*a*) assessment of an insecticidal treatment and with refinement, and (*b*) an accurate census of nymphal and adult phasmatids. Durable traps, with suitable coverings to retain the frass pellets, should be provided for long-term studies.

5. Egg production measurement provides a good check against frass fall measurement when the phasmatids are mature.

6. Detailed studies are necessary of the mortality factors acting on the nymphal and adult stages if the initial predictions are to be related to the probable defoliation of an affected area.

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Appendix 1.

Figures of Egg Dissections of Survey made 3–6/6/1957.

Site No.	Advanced Embryos.	Developing Embryos.	Un-developed Eggs.	Parasitized Eggs.	Diseased and Deteriorating Eggs.	Empty Shells.	Total.
Tuggolo State Forest.							
1	1		6		9	33 (6)	49 (6)
2	4		9		16 (1)	53 (1)	82 (2)
3	11		7	3	41 (3)	29 (5)	91 (8)
4	29		9	10	39 (1)	61 (10)	148 (11)
5	4		6	7	8	22	47
6	15		3	4	5	21 (2)	48 (2)
7	13	3	16	13	15 (1)	23 (4)	83 (5)
8	119	5	36 (1)	45	197 (1)	121 (27)	529 (29)
9	13		8	9	16	23 (5)	69 (5)
Total	209	8	100 (1)	91	346 (7)	386 (60)	1140 (68)
Tomalla State Forest.							
Nth. Junction of Collisons and S.G. Road	23		6 (1)	8	24 (1)	48 (24)	109 (26)
Margin of attack 1955/56	2	1	3	2	15 (3)	14 (7)	37 (10)
South of track ..	2		1	5	8 (5)	19 (24)	35 (29)
Edge of attack 1955/56	6		5	10	13 (2)	32 (5)	66 (7)
Total	33	1	15 (1)	25	60 (11)	113 (60)	247 (72)
Nundle State Forest.							
Below lookout Section	1 (1)		3		138 (18)	184 (78)	326 (97)
Big Flat near Murder Dog	5 (2)		2	20	12	36 (2)	75 (4)
One mile west of Murder Dog	15			18	8	16	57
Edge of past defoliation Murder Dog.. ..	1		2		4	14 (5)	21 (5)
Peppermint Flat ..	53	1	25 (1)	20	45 (2)	154 (34)	298 (37)
Snowball Break ..	16		4	2	15	18 (1)	55 (1)
One mile east of Snowball Break ..	6 (1)		8	1	5	7 (1)	25 (2)
Total	96 (4)	1	44 (1)	61	227 (20)	429 (121)	857 (146)

These figures are for eggs of *P. wilkinsoni*; those in brackets denote *D. violescens*.

APPENDIX 2.

(A.)

State Electricity Commission–Kiewa Area. Dissection of Eggs of *D. violescens* 30–31/10/57.
(Litter samples collected by H. Vyner.)

Site No.	Advanced Embryos.	Partly Developed Embryos.	Un-developed Eggs.	Parasitized Eggs.	Diseased and Deteriorating Eggs.	Total.	Empty Shells.	Grand Total.
1. Above Bogong Township	1	—	20	—	4	25	2	27
2. Above Bogong Township	—	—	12	—	3	15	1	16
3. Railhead Bench ..	—	—	17	—	2	19	10	29
4. ,, ,, ..	1(*e*)	1	9	2	5	18	5	23
5. 6–7 mile peg—No. 1 Road	—	—	4	—	2	6	1	7
6. 6–7 mile peg—No. 1 Road	3(*e*)	1	33	15	6	58	25	83
7. 6–7 mile peg—No. 1 Road	—	—	11	7	1	19	1	20
8. Bogong Lodge—No. 1 Road	1(*e*)	—	8	—	1	10	9	19
9. Pretty Valley Bridge	—	—	4	—	1	5	4	9
10. 11–12 mile peg—No. 1 Road	—	—	4	—	2	6	3	9
11. 11–12 mile peg—No. 1 Road	—	—	4	—	—	4	3	7
12. Test Point No. 11 ..	—	—	1	—	—	1	—	1
Total	6 (3·3%)	2	127 (68·4%)	24 (12·8%)	27 (14·5%)	186	64	250

(B.)

(Forest litter samples collected 3/3/58 by H. Vyner.)

Site No.	Advanced Embryos.	Un-developed Eggs.	Parasitized Eggs.	Diseased and Deteriorating Eggs.	Total.	Empty Shells.	Grand Total.
1. Above Bogong Township	16	5	2	9	32	6	38
2. ,, ,, ,,	4	—	—	6	10	3	13
3. Railhead Bench	—	—	—	—	—	—	—
4. .. ,, ...	1	1	1	1	4	2	6
6. 6–7 mile peg—No. 1 Road	1	—	—	—	1	5	6
6. ,, ,, ,, ,,	15	4	24	14	57	41	98
7. ,, ,, ,, ,,	1	1	2	1	5	1	6
8. Bogong Lodge—No. 1 Road	2	1	—	7	10	10	20
9. Pretty Valley Bridge ..	24	6	1	9	40	23	63
10. 11–12 mile peg—No. 1 Road	1	—	—	9	10	8	18
11 ,, ,, ,, ,,	1	1	—	1	3	5	8
12. Test Point No. 11 ..	—	—	—	—	0	1	1
Total	66 (30%)	19 (11%)	30 (17%)	57 (33%)	172	105	277

APPENDIX 3.

Dissection of Eggs Collected at Island Bend, S.M.H.E.A., June 1957.
Phasmid : *Didymuria violescens* Leach.

Site No.	Advanced Embryos.		Undeveloped Eggs.	Parasitized Eggs.	Diseased and Deteriorating Eggs.	Total Eggs with Contents.	Empty Shells.	Grand Total.
	Alive.	Dead.						
1	—	—	—	2	—	2	1	3
2	1	1	21	19	49	91	119	210
3	17	1	67	5	69	159	240	399
4	11	1	56	—	56	124	179	303
5	9	1	23	7	63	103	205	308
Total ..	38 (9%)	4 (1%)	167 (35%)	33 (7%)	237 (48%)	479	744	1223

APPENDIX 4.

(A.)

Didymuria violescens Leach.
Bago S.F.—Cpts. 34 and 35.

Site No.	Advanced Embryos.	Partly Developed Embryos.	Undeveloped Eggs.	Parasitized Eggs.	Diseased or Deteriorating Eggs.	Total.	Empty Shells.	Grand Total.
34/1	28	1	4	—	27	60	7	67
34/2	8	—	4	2	65	79	93	172
34/3	34	—	6	3	44	87	34	121
34/4	84	—	27	2	37	150	101	251
35/1	15	1	6	2	36	60	207	267
35/2	171	—	41	4	153	369	120	489
35/3	91	—	30	4	81	206	85	291
Total ..	431 (43%)	2 (0·2%)	118 (12%)	17 (1·7%)	443 (44%)	1011	647	1658

(B.)

Didymuria violescens Leach—Bago S.F.
Egg Dissections—Collected 29–30/9/58.

Site No.	Advanced Alive.	Embryos Dead.	Partly Developed Embryos.	Undeveloped Eggs.	Parasitized Eggs.	Diseased or Deteriorating Eggs.	Total.	Empty Shells.	Grand Total.
Cpt. 36 near S.W. corner of Cpt. 35	56	7	2	23	2	89	179	189	368
Cpt. 35 near NC.. ..	6	1	—	3	—	30	40	12	52
Cpt. 35 near J24 ..	19	3	—	12	—	38	72	89	161
Cpt. 34 toward B33 ..	35	2	—	6	5	46	94	52	146
Cpt. 34 near B35 ..	12	—	—	2	—	28	42	113	155
Total ..	128 (30%)	13 (3%)	2 (0·4%)	46 (11%)	7 (1·6%)	231 (54%)	427	455	882

APPENDIX 5.
Total Frass Fall in Grammes per 20 Traps per 24 Hours.
Bago State Forest.

Block.	5/3	6/3	7/3	8/3	9/3	10/3*	11/3	12/3	13/3	14/3	23/4	34/4
C	100·92	82·97	69·14	88·57	117·33	15·06	88·53	70·46		46·60	59·26	69·49
D	139·34	72·39	61·56	74·13	111·07	15·11	77·96	67·94	75·12	10·99	57·00	69·91†
B	57·84	26·16	24·51	27·88	32·61	5·48	29·41	25·01	33·47	5·06	28·50	30·40†

* 5 plots measured only because of rain.
† 19 plots only, one damaged.

Frass Production by *D. violescens* held at Epping, N.S.W., fed *Eucalyptus andreana*.

	Number of Insects.		Dates 1957.	Total Fæcal Production in Grammes per Hour (O.D.W.).
	Male.	Female.		
(*a*)	1	2	23/3–24/3	0·0120
			24/3–25/3	0·0109
			25/3–26/3	0·0099
			26/3–27/3	0·0104
(*b*)	2	4	23/3–24/3	0·0266
			24/3–25/3	0·0276
			25/3–26/3	0·0283
			26/3–27/3	0·0290
(*c*)	12	46	18/3–19/3	0·202
			19/3–20/3	0·190
			20/3–21/3	0·212
			21/3–22/3	0·348
			22/3–23/3	0·264
			23/3–24/3	0·206
			24/3–25/3	0·211
			25/3–26/3	0·201
			26/3–27/3	0·216

APPENDIX 6.
Egg Production per Trap—Bago State Forest.
D. violescens.

Area.

Plot.	Period.			Plot.	Period.			Plot.	Period.		
	12/3–2/4	3/4	4/4		12/3–2/4	3/4	4/4		12/3–3/4	3/4	4/4
C1	*	41	24	D1	*	50	55	B1	*	4	1
2	503	28	38	2	569	59	61	2	144	13	15
3		10	14	3		15	14	3	139	10	18
4		24	30	4		19	19	4		7	8
5		13	22	5		6	12	5	136	16	14
6		33	10	6		28	32	6		7	14
7		35	39	7	Plot destroyed†			7			
8		14	20	8		2		8	185	8	6
9		9	9	9	595	26	37	9		2	2
10		25	23	10	240	13	16	10		2	1
11		4	30	11	213	9	13	11	52	7	6
12	128	8	11	12		19	34	12	95	13	8
13		24	29	13			3	13		8	7
14	261	21	23	14	340	12	18	14		14	24
15		30	39	15	407	12	19	15	201	22	15
16	401	24	29	16		25	23	16	211	5	16
17		7	9	17	660	62	78	78		—	—
18		13	13	18	416	23	25	18		2	1
19	104	9	16	19		3	6	19		—	2
20	9	9	6	20		24	45	20		—	1
Total		381	434			407	510			140	159
Mean P=0·05*t*		19·5 ±5·0	21·7 ±4·8			21·4 ±8·6	26·8 ±9·8			7·1 ±2·7	7·5 ±3·3

* Some of the plots were damaged so the figures for egg production could not be relied upon and were not used.
† Plot No. D7 was smashed during the period 12/3–2/4 and was not used thereafter.